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Enclosure E1 (Formerly referred as Attachment E1)

CONSTRUCTION QUALITY CONTROL AND CONSTRUCTION QUALITY ASSURANCE

(CQC/CQA)

OF CLAY LINER/FINAL COVER

CONSTRUCTION QUALITY CONTROL AND
CONSTRUCTION QUALITY ASSURANCE (CQC/CQA)
OF CLAY LINER/FINAL COVER

This document puts forth guidance regarding construction of clay liner and final cover. This document should not be construed as Agency policy in this regard, but rather, as guidance to staff and perhaps to the regulated community. It is recommended that this guidance be used for preparation of the CQC/CQA plan for a permit application for a new landfill and a permit modification for horizontal expansion and/or vertical expansion. The CQC/CQA must be submitted along with the new permit application/modification.

At a minimum, the following information and/or narrative shall be included in the CQC/CQA plan:

1. Summary of owner(s) and contractor(s)/subcontractor(s) qualifications and responsibilities during the construction of the facility. At a minimum, the following shall also be defined/provided;

    - Owner delegation of authority.
    - Owner/operator relation to others.
    - Design engineer relation to others.
    - Weather and work stoppage.
    - CQC personnel relation to others.
    - Independent CQC/CQA laboratory services contractor(s).

2. CQC and CQA personnel qualifications, responsibilities, and authority must be provided. The CQA officer, CQC inspector(s) and all other CQA/CQC personnel must have adequate training and related experience to perform their responsibilities. At a minimum, the following individual qualifications must be provided where applicable:

    - Manufacturers/fabricators
    - CQC/CQA personnel, etc.

    "Construction quality control" or "CQC" means a planned system of inspections that is used to directly monitor and control the quality of a construction project. Construction quality control is normally performed by the geosynthetics manufacturer or installer, or for natural soil materials by the earthwork contractor and is necessary to achieve quality in the constructed or installed system. Construction quality control refers to measures taken by the installer or contractor to determine compliance with the requirements for materials and workmanship as stated in the approved construction plan.

    "Construction quality assurance" or "CQA" means a planned system of activities that provides assurance that the facility was constructed as specified in the approved construction

plan. (Continued next page.)
Construction quality assurance includes inspections, verifications, audits and evaluations of material and workmanship necessary to determine and document the quality of the constructed facility. Construction quality assurance refers to measures taken by a project engineer to assess if the installer or contractor is in compliance with the approved construction plan.

3. Engineer oversight and certification responsibilities during the construction of the facility must be provided.

4. Establishment of a construction grid system on-site for horizontal and vertical control and reference of work on full-size liner must be provided.

5. Construction specifications such as the following must also be provided.

    - Material - addition or removal of moisture.

    - Construction methods - type of equipment to be used.

    - Compaction specifications - Modified vs. Standard Proctor density, lift thickness and number of passes.

    - Testing requirements - grain size, Atterberg limits, density test (Nuclear and/or lab) and hydraulic conductivity.

6. Method of amending the soil and specifications of soil amendments, if applicable, must be provided.

7. Soil liner compatibility data, if applicable, must be provided.

8. A description of the inspection tasks, sampling, testing methods and test frequencies to be employed during the construction of the facility must be provided; See Table 1 for test frequency.

9. Acceptance/rejection criteria for specific test and problem resolution procedures must be provided.

10 Design construction tolerances must be provided.

11. Corrective actions must be taken if some part of the work fails to meet the regulatory and design standards. Problem identification and corrective measure.

12. Control of desiccation and protection against freezing must be provided.

13. Post-installation activities must be provided.

14. Custody, record drawings, professional certification and the contents of the CQA documentation report must be provided.

15. Additional information as may be required by the Commissioner.

16. Preconstruction activities and material evaluation. At a minimum, the following information must be provided:

    A. <u>Preconstruction Activities and Material Evaluation</u>

    1) Review of the design drawing and specifications.

    2) Take preconstruction samples as recommended in Table 1 and analyze for:

        a. Grain size (ASTM D 422).

        b. Atterberg limits (liquid limits and plasticity index) (ASTM D 4318).

        c. Standard or modified Proctor maximum dry density (ASTM D 698, ASTM D 1557), respectively.

        d. Hydraulic conductivity (EPA 9100) or equal (ASTM D5084).

        e. Water content (ASTM D2216).

    3) At a minimum, the material evaluation as mentioned above for the compacted clay liner and clay final cover must meet the following specifications:

        a. Soil must be a Unified Soil classification of ML, CL, MH, or OH.

        b. Soil must contain a minimum of 50% by weight which passes the No. 200 (0.075 mm) sieve.

        c. Soil must have a clay content of 25% (less than or equal to 0.005 mm) by weight or greater.

        d. Soil must have a plasticity index of 10 or greater.

e. Soil must have saturated hydraulic conductivity of not more than $1x10^{-7}$ cm/sec.

f. In the event that the above-mentioned specifications don't fully meet the criteria, but the hydraulic conductivity of 1×10^{-7} cm/sec. or less can be achieved, the Commissioner may allow deviation from the specified criteria.

17 For drainage layer material, obtain a sample of sand and/or gravel from the proposed supplier and perform grain size analysis and hydraulic conductivity tests as recommended in Table 1.

18. Construct a test fill from the proposed soil to be used for the clay liner.

19. Test Fill Construction and Documentation - The purpose of a test fill is to verify that the specified density, moisture content and hydraulic conductivity can be achieved before a full size liner is built. Normally, a test fill is approximately 3 feet thick, 40 to 80 feet long, and 20 to 40 feet wide. The material and construction practice which is used for construction of a test fill should follow the same procedures as closely as possible to the full size liner. In-situ hydraulic conductivity testing should be performed on the test fill to confirm the desired hydraulic conductivity of not more than 1×10^{-7} cm/sec. The following methods are acceptable for this type of test:

1) Sealed double-ring infiltrometer (SDRI).

2) Boutwell borehole test, with a minimum of five (5) tests required.

3) Shelby tube (carved block) test using a twelve (12) inch diameter tube, with a minimum of three (3) tests required.

4) Other equivalent test methods approved by the commissioner.

CQC and CQA must be documented for the test fill and the test results submitted as part of the as-built report.

20. Liner construction activities. The very general steps involved during the construction of the clay liner are outlined below.

A. <u>Preparation of Foundation</u>

1) Strip and excavate as necessary to remove all soft, organic, permeable and other undesirable materials. Proof-rolling with heavy equipment as needed to detect soft areas which may cause settlement.

2) Filling of fractures, depressions, and any areas where undesirable material has been removed. Backfill material must be compacted to the required design specification or grouting materials.

3) The foundation surface may be disked or tilled to a depth of 1 to 2 feet and recompacted as needed to provide good contact between the foundation soil and the clay liner.

4) Upon completion of foundation construction, the entire base and side wall should be smooth drum, seal-rolled to prevent puddles or ponds on the foundation surface

5) A final proof-rolling is also recommended.

B. Clay Liner Installation

1) Liner Material Emplacement:

a. The liner is placed in a series of lifts.

b. Lift thickness is a function of the following:

- Soil characteristics.
- Size and type of compaction equipment.
- Required compactive effort.
- Generally, 6 to 9 inches thick, loose lift is recommended.

c. Percent Proctor density - A minimum of ninety-five percent (95%) standard Proctor density or ninety percent (90%) modified Proctor density has been recommended for adequate compaction. Soil placement with a density of less than 93% of standard Proctor density must be rejected. No more than five percent (5%) of density values can be below 95% as long as these failures are not concentrated in one lift or in one area. Another approach will be acceptable if an envelope of acceptable density/moisture content can be developed to show that the desired hydraulic conductivity can be achieved with a lower or higher compaction effort.

d. The liner material is generally placed with a scraper-pan or trucks and then distributed with a dozer or grader or other equipment.

e. Type of compaction equipment, including weight and number of passes. The following is a list of equipment which is being used for compaction of the clay liner, depending upon the type of soil being compacted:

- Sheepsfoot or clubfoot roller.
- Padfoot (pegfoot or wedgefoot) roller.
- Vibrating sheepsfoot roller.

Compaction equipment weighing 40,000 pounds or more is recommended. On the side slop, lighter equipment may be adequate with additional passes.

Caterpillar 815, 825, and 826 are being effectively utilized for the compaction of clay liners.

f. After each lift segment is installed, it is beveled or stepcut (see figure 1 with grading equipment to ensure proper keying into the next or previous segment. This procedure eliminates potential pathways for seepage through the liner along the boundary.

2) Clod size reduction:

a. After the placement of each lift, the liner material must be broken up for homogenization and clod size reduction. This is very important because the clod size will affect moisture control and compaction operations. The smaller the clod size, the better will be the homogenization and compaction achieved.

b. Clod size of 1 to 2 inches or smaller is recommended.

c. Clod size can significantly affect the hydraulic conductivity of the liner. Clod size reduction is usually accomplished using disk harrows or rotary tillers with various shaped tilling blades. Table 2 shows the effect of clod size on the hydraulic conductivity of the compacted clay liner.

3) Moisture control:

a. This could mean addition or removal of moisture from the liner material to achieve the specified compaction moisture content.

b. Proper and uniform moisture content is an important factor for compacting soil material to achieve the desired hydraulic conductivity.

c. Minimum hydraulic conductivity can be obtained if the clay material is compacted on the "wet side of optimum" (0 to +5%). Typical values for various clayey silt (ML)(Wopt + 2%), for sandy clays, silty clays, or silty soils (CL, MH) (Wopt + 3%) and for fat clay (CH) (Wopt +5%). (Reference 3, p. 198).

d. Make sure that prior to and during construction of the liner, the moisture is uniformly applied and distributed.

e. Uneven moisture may cause inadequate breakup of large clods prior to compaction.

f. Moisture is generally added to liner material prior to placement of clay materials.

g. Moisture addition is accomplished by sprinkler trucks, sprinkler system, etc. Added moisture must be thoroughly mixed. this can be done with disk harrows, rotary cultivators pulvi-mixing.
Adequate equilibration time after moisture addition is critical to ensure uniform moisture in the materials

C. <u>Methods of Keying In Liner Segment</u>

Scarification and/or bonding between lifts is considered essential to bonding soil lifts together during soil compaction activities in order to achieve in-situ hydraulic conductivity of not more than 1×10^{-7} cm/sec. If this is not properly achieved, it can result in increased horizontal hydraulic conductivity along the lift interface. Two measures have been recommended:

1) Scarification of the previous lift by disk harrow or other device;

2) Control of moisture content of the adjacent lifts so that they are equivalent as specified in the design.

D. <u>Control of Desiccation</u>

Consideration should be given to the following items in order to prevent desiccation.

1) If applicable, perform waste compatibility on the liner to confirm that cracking from chemical attach will not occur.

2) The liner material should be tested for liquid, plastic and shrinkage limits.

3) Generally, soils with high volume changes have a greater tendency to crack with decreased moisture.

4) Clay liners may be subject to developing desiccation cracks during and immediately after installation. This can be prevented by placing 2 to 3 feet of drainage blanket, protective cover or synthetic membrane on top of the liner.

E. <u>Freezing</u>

Special consideration should be given to the following:

1) Do not construct liner with frozen soils.

2) The liner becomes difficult to work and compact with decreasing temperature.

3) It is difficult to achieve the desired density and hydraulic conductivity.

4) Construction of liner in cold climate during the months of December, January and February is not recommended.

5) Freezing of liner could cause surface cracking and desiccation of soil which could result in increased hydraulic conductivity of the liner.

6) The liner must be protected from freezing by a blanket of soil when the temperature drops below freezing.

F. <u>Post Installation Activities</u>

1) Upon completion of the liner, it must be rolled smooth to seal the surface so that precipitation can run off freely.

2) The completed liner must be surveyed, preferably by laser, to confirm the thickness, slope, etc., as required by design specifications.

3) The liner must be covered with plastic or cover soil to prevent desiccation prior to installation of the next system components (e.g., geomembrane or leachate collection system).

21. **<u>The following are potential causes for failure of the clay liner and clay final cover that can be avoided with careful CQC/CQA:</u>**

A. Use of material that does not meet the design specifications.

B. Inadequate foundation preparation.

C. Inclusion of roots, large rocks, pockets of permeable materials and other foreign objects in the liner material.

D. Inadequate moisture control, both prior to and after compaction.

E. Inadequate clod size reduction, mixing and spreading of liner materials.

F. Failure to follow installation procedures specified in the design.

G. Use of improper or inadequate construction equipment.

H. Application of inadequate compactive effort.

I. Failure to tie lifts together properly.

J. Inadequate control of soil moisture content and density during compaction and poor maintenance after construction.

This document may be modified periodically to reflect changes in methodology. If you have any questions regarding this guidance, please contact Solid Waste Engineering staff of this office for assistance.

Attachment

Table 1
Clay Liner and Clay Final Cover Recommended Minimum Testing Frequencies During Construction

	Item	Testing	Frequency
1.	Test Fill	Sealed Double-Ring Infiltrometer Test or others if equal or better results are provided.	Once if same soil and same equipment is used and whenever soil and/or equipment change.
2.	Pre-construction Activities Evaluation Testing Frequencies.	Grain Size	Every 5,000 Cubic Yards or Soil Material Change
		Moisture	Every 5,000 Cubic Yards or Soil Materials Change
		Atterberg Limits (liquid limit and plasticity index)	Every 5,000 Cubic Yards or Soil Material Change
		Moisture-Density Curve	Every 5,000 Cubic Yards or Soil Material Change
		Lab Hydraulic Conductivity (remolded samples)	Every 10,000 Cubic Yards
3.	Off-Site Clay Borrow Source Testing	Grain Size	Every 1,000 Cubic Yards
		Moisture	Every 1,000 Cubic Yards
		Atterberg Limits (liquid limit and plasticity index)	Every 5,000 Cubic Yards
		Moisture-Density Curve	Every 5,000 Cubic Yards and all Changes in Material
		Lab Hydraulic Conductivity (Remolded samples)	Every 10,000 Cubic Yards
4.	Clay Liner Testing During Construction	Density (nuclear or sand cone)	5 Tests Per Acre Per Lift evenly distributed
		Moisture Content	5 Tests Per Acre Per Lift evenly distributed
		Undisturbed Hydraulic Conductivity	1 Test Per Acre Per Lift
		Dry Density (undisturbed sample)	1 Test Per Acre Per Lift
		Moisture Content (undisturbed sample	1 Test Per Acre Per Lift
		Atterberg Limits (liquid limit and plasticity index)	1 Test Per Acre Per Lift
		Grain Size (to the 2-micron particle size)	1 Test Per Acre Per Lift
		Moisture-Density Curve (as per clay borrow requirements)	Every 5,000 Cubic Yards and all changes in material
5.	Granular Drainage Blanket	Grain Size (to the No. 200 sieve)	1 Test Per 1,500 Cubic Yards or 2,400 ton
		Hydraulic Conductivity Test	1 Test Per 3,000 Cubic Yards or 4,800 ton
6.	Bedding material around the perforated collection pipe; eighty-five percent (85%) of the backfill materials shall have a diameter greater than the diameter of the pipe perforation.	Grain Size (to the No. 200 sieve)	1 Test per 1,500 Cubic Yards or 2,400 ton or minimum of 3 test. 1 Test Per 3,000 Cubic Yards or 4,800 ton or minimum of 3 test

All Testing must be performed in accordance with the American Society for Testing and Materials (ASTM)

TABLE 2

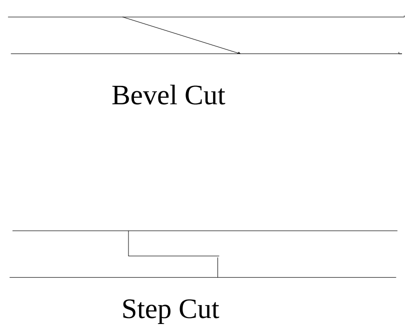
EFFECT OF CLOD SIZE ON PERMEABILITY OF LABORATORY COMPACTED CLAY

Maximum size of clods (in.)	Permeability (cm/s)
3/8	2.5×10^{-7}
3/16	1.7×10^{-8}
1/16	8.5×10^{-9}

Source: Daniel, 1981

Source: Reference 1

FIGURE 1



Source: Reference 1

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3. Peck, R.B. Hanson, W.E. and Thornburn, T.H., "Foundation Engineering", Second Edition, John Wiley and Sons, 1974, p. 198.

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5. "Requirement for Hazardous Waste Landfill Design, Construction and Closure", U.S. Environmental Protection Agency, EPA/625/4-89/022, pp. 89-98.

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